



# Finite Element Analysis of the Ellis Island Ferry

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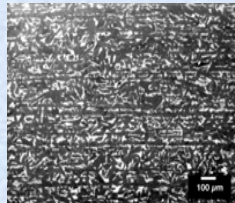
Historic shipwrecks are valuable cultural resources continuously under attack by their environment. After carrying immigrants to Manhattan from 1901 to 1953, the Ellis Island Ferry sank at her moorings in 1968. To study the stability of the wreck under several salvage scenarios, a finite element model was created of the Ellis Island using ABAQUS. The model was constructed out of shell and beam elements, whose thickness was left as an open variable so that thinning of member due to corrosion, could be taken into account. The ship was assumed to make firm contact with the mud and water, and all riveted and otherwise joined sections were assumed to behave like base metal and have no special considerations associated with them. The actual densities of the mud, seawater and iron were used in order to include body forces induced by gravity. Since it would have a great influence on the details of the collapse, the tilt angle of seven degrees about the lengthwise axis was included to accurately resolve the forces inducing collapse. From the simulation, the high stresses region with the wreck was identified. The stresses changes were predicted by modifying the conditions including thinner hull and removing mud and water, etc.

## Ellis Island Ferry



## Metallurgy

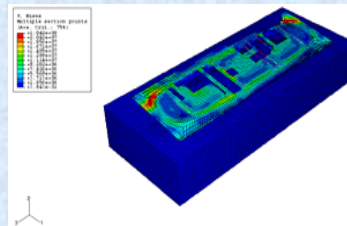
Scanning Electron Micrograph of steel sample from ferry Ellis Island



Chemical analysis:  
C: 0.15 % with 1% Mn and 0.05% S  
Rockwell hardness: 65 +/-3 HRB  
A standard ferrite/pearlite with hot rolled and air cooled without normalization, very typical for ship steel hull plate of the era.

## Finite Element Model

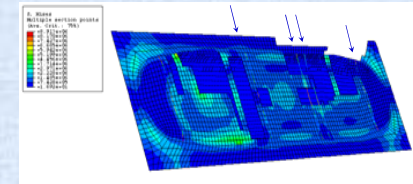
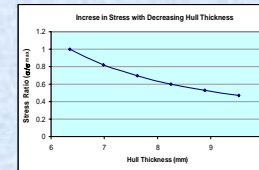
- The ship were idealized to remove details about the propellers, rudder and superstructure. The deck was idealized to be rectangular rather than an oval, and was put in place intact.
- Ship: 7 degree angle, plate and shell element, classical metal plasticity.
- Outside and inside water saturated mud: solid element, Mohr-Coulomb plasticity.
- Procedure: adding gravity, water and mud pressure and then remove the inside water and mud, ....



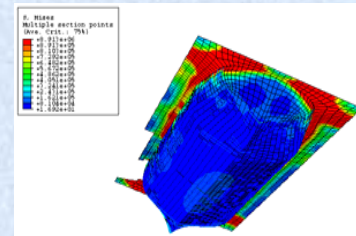
Finite Element model with the boat, inside and outside mud

## Physical Scenarios Examined

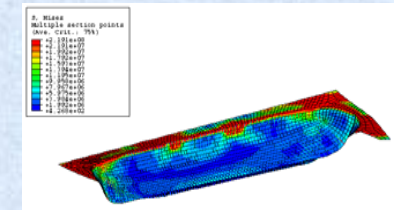
Remaining strength with thickness of that portion of the hull that juts above the water



Stress view from the top. Note especially the high stresses (red) in the four beams that are continuous across the width of the ship, indicate by the arrows. These four remaining members across the deck are essentially holding the upper portion of the ship together and restraining the hull from spreading apart.



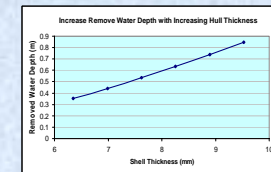
Stress view from below and side. Note especially the low stresses in the hull, which is being held in place by the mud and water both inside and out. The highest stresses are in the region where the decking attaches to the hull, because of the large bending moment being put on the joint by the overhanging weight of the deck.



## Stability of the wreck upon removing of water and mud inside and out

Removal of the mud and water leads to very large changes in the loading and thus the stability

We performed a simulation on a cross-section of the hull where we decreased the water depth a fixed amount, then iterated the thickness of the hull needed to just keep the water outside from collapsing the structure.



Removal of just the water from the inside was sufficient to collapse the wreck inward.

## Acknowledgement

We would like to thank the National Park Service's Submerged Resources Center for the financial support, providing ferry boat and underwater mud survey data.

## Summary

The simulation results indicated that the mud is essentially supporting the hull and keeping it in its present shape. Removal of the mud and water leads to very large changes in the loading and thus the stability. It is recommended not to raise the wreck, but rather conserve in place.